Actually, the concept of optimized maintenance (or proactive maintenance) has always existed in the minds of maintainers. When vibration analysis required expensive, cumbersome equipment and substantial investments of time, it was used sparingly, on critical machines. Now, it is applied generally throughout the plant.

An optimization decision.. should a bearing be stocked in plant, or do you take a chance on it being carried by the supplier? Everything would be stocked in plant if it didn't cost anything.

An optimization decision...refit the impeller on a centrifugal pump every N hours? Or, better to change it on a schedule rather than have the pump efficiency drop dramatically (or have the pump fail) in a random fashion.

The task of condition monitoring, be it vibration analysis, wear particle analysis, thermography, ultrasonic crack detection or whatever, is purely an optimization trade-off. It is better (closer to optimal) to spend X amount of dollars gathering data than to spend the Y amount of downtime and repair dollars that will probably be necessary should the data not be collected.

The intelligent condition monitoring system determines the optimal mix of maintenance methods to use, based on the data it possesses, and updates this mix based on the results of the current mix. Simply put, it changes its behavior in response to feedback, just like any other intelligent creature.

Figure 3 is the conceptual model for an intelligent condition monitoring system.

The Configuration Module sets up the measurement parameters for the other subsystems. For example, the embedded knowledge within the Configuration System would be used to establish condition monitoring methods, recommendations for part stocking levels, initial schedules for planned maintenance, etc. These initial settings would be updated whenever input from the Optimization Module is received.

For example, if a plant has a series of 40 identical motor-centrifugal pump combinations; the Configuration Module, knowing the capabilities (and costs) of various condition monitoring tools, parts and labor necessary for maintenance procedures, and the costs associated with downtime and/or unscheduled repair, would produce an initial Maintenance Plan for these pumps. The plan could involve such tests as velocity spectra readings, HFDs, envelopes (demodulated spectra), motor current monitoring, lubricant analysis, ferrography, motor thermography, etc. Certain parts may be earmarked for on-site stocking. Some maintenance procedures may be scheduled by running hours or by time.

Once a maintenance plan has been established, it is communicated to the next three modules in the system...condition analysis, maintenance scheduling and the parts/ labor/equipment database.

The Condition Analysis Module is the clearing house for condition monitoring data. It takes in data from the vibration analysis subsystem, lubrication analysis subsystem, and other condition monitoring subsystems. Also, data available in digital control systems should be accessible by this module. This data is cross-correlated to each other and fed to one or more "knowledge blocks". These knowledge blocks can be implemented as rule bases, nets or other knowledge representation schemes.

The essential characteristic of the Condition Analysis Module is that it acts as an intelligent data filter, reducing a substantial volume of data into an "exception set": a relatively small list of diagnoses and/or recommended actions that can be fed to the Maintenance Scheduling Module.

The Maintenance Scheduling Module controls the allocation of maintenance resources. Although it can use standard scheduling modes such as running hours, calendar hours or mileage, it will also allow tasks to be triggered by the Condition Analysis Module. Also, any scheduled maintenance action can be used as a "hot trigger" to schedule one or more other maintenance actions.

Maintenance scheduling has traditionally been semi-automated, utilizing scheduling algorithms ranging from low to moderate complexity. The maintenance management system generally schedules equipment maintenance based on calendar days or equipment running hours. The maintenance planner then uses his knowledge of upcoming activity, current status and a number of other factors to manipulate the schedule. Generally, maintenance management systems take little or no direction from condition monitoring findings.

The goals of the Maintenance Scheduling Module are to integrate the maintenance subsystems into the maintenance scheduling process, allowing condition and performance monitoring findings to be used effectively for maintenance planning; and to increase automation of the maintenance planning process itself, reducing the need for extensive manual intervention when maintenance schedules are produced.

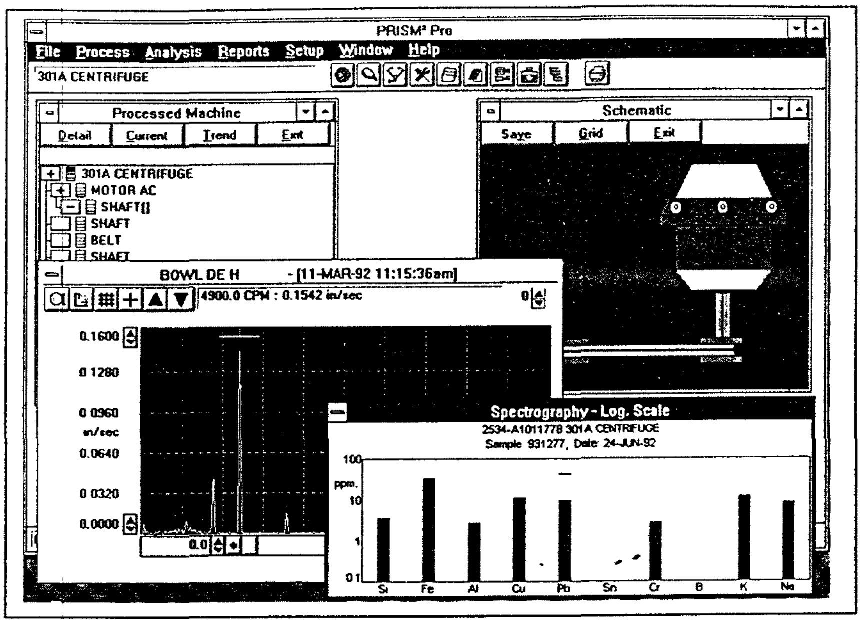

Figure 1 - Prism^{2}Pro version 2.00

The task of condition monitoring, be it vibration analysis, wear particle analysis, thermography, ultrasonic crack detection or whatever, is purely an optimization trade-off. It is better (closer to optimal) to spend X amount of dollars gathering data than to spend the Y amount of downtime and repair dollars that will probably be necessary should the data not be collected. The intelligent condition monitoring system determines the optimal mix of maintenance methods to use, based on the data it possesses, and updates this mix based on the results of the current mix. Simply put, it changes its behavior in response to feedback, just like any other intelligent creature.

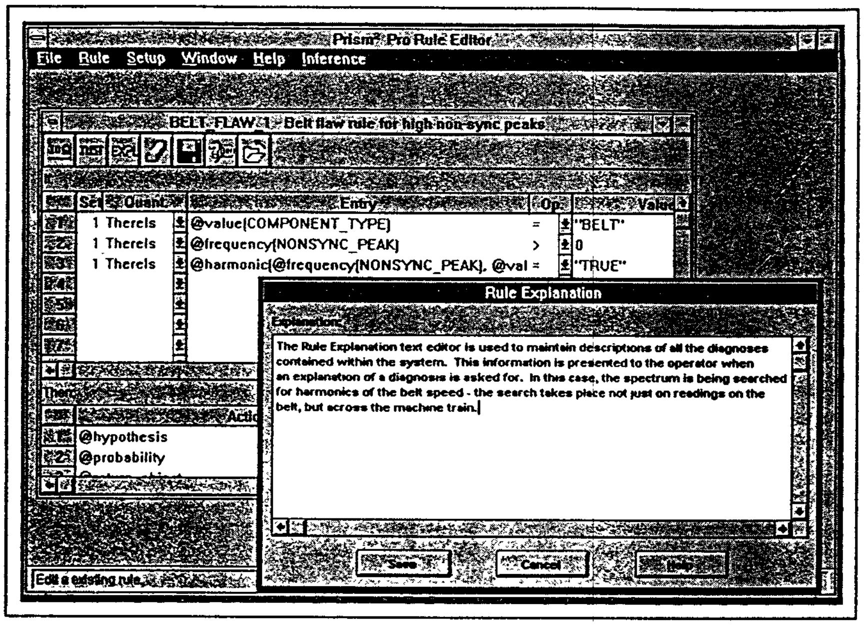

Figure 2 -
Use of a knowledge editor

To achieve these goals requires a system with the following attributes:

• A maintenance scheduling system that is able to integrate results (the "exception set") received from the Condition Analysis Module, with more traditional scheduling methods such as running hours, mileage, output counts, etc.

• The ability to launch the processing procedures of all of the maintenance subsystems. This launching capability must work both on single workstations and across networks. This ensures that the exception sets being used by the maintenance scheduling system are as up to date as possible.

• A customizable "task scheduling rule base" that allows the end user to tailor the scheduling of maintenance activity without programmer intervention. This system would need restricted access via a password.

The system can use predictive maintenance results in a manner that is familiar and comfortable to maintenance engineers. One of the difficulties of condition monitoring has been integrating machine condition data with day-to-day and long-term maintenance planning. If machine condition findings are automatically handled in the same way that running hours and calendar hours are handled, these findings will seem more relevant to maintenance planners/operators.

A maintenance schedule, in its traditional form, can be thought of as a primitive rule base. For example, the standard running hours method of determining if an impeller needs to be overhauled can be described as follows:

IF machine is a centrifugal pump
AND machine running hours>machine scheduled impeller overhaul period
THEN activate (overhaul impeller work order)

This rule is a basic rule stating that if the running hours of the machine are greater than the maintenance period for the impeller, then a task is activated (a work order) to overhaul the impeller. Nothing is implied about the impeller's condition, simply that it is time for overhaul.

An intelligent "task scheduling rule base" would extend this comparatively simple process to one that has a higher degree of customizability by the end user. Tasks are then activated by values found in the equipment database and the condition monitoring exception set.

For example, one could add to the above rule the following rules:

IF machine is a centrifugal pump
AND diagnosis is "vane defect"
AND diagnosis is severity>MODERATE
THEN activate (overhaul impeller work order)
IF machine is a centrifugal pump
AND machine overhaul impeller work order is ACTIVE
AND machine is component (MOTOR AC) is TRUE
AND historical diagnosis (180 days) is "electrical motor fault"
THEN activate (inspect electric motor work order)

In this instance, the presence of a high or severe vane problem is the trigger that activates the task "overhaul impeller". In addition, the fact that this task is now active is then used to activate a task to "inspect the electric motor" (if the pump is driven by a motor, and there has been any evidence of an electrical motor problem on this pump within the last six months).

The benefits of such a rule-based maintenance planning system are:

• The system can use predictive maintenance results in a manner that is familiar and comfortable to maintenance engineers. One of the difficulties of condition monitoring has been integrating machine condition data with day-to-day and long-term maintenance planning. If machine condition findings are automatically handled in the same way that running hours and calendar hours are handled, these findings will seem more relevant to maintenance planners/operators.

• The system can embody the knowledge of the maintenance planner. The knowledge that task A should be scheduled if task B is scheduled often resides solely in the maintenance planner's head, as this capability is difficult to implement in a conventional planned maintenance system. This can greatly reduce the amount of manual operation required to produce daily and weekly maintenance schedules; as much of the schedule "tweaking" that is generally required can be automated in the rule base.

The use of a rule-based task scheduler as a module of the intelligent condition monitoring system increases the applicability and usability of the entire condition monitoring program.

The parts/labor/equipment module is similar in function to the standard record keeping functions found in most maintenance management systems. The primary purpose of this module is to maintain current cost information and a history of repairs/maintenance action taken on each piece of equipment.

This module should in fact (if it is at all possible) be the maintenance management software that is currently in operation. This would allow the integration of the intelligent condition monitoring system without overly disrupting current practice. This would require certain maintenance management software capabilities, mainly in the area of accepting externally produced data. These capabilities may already exist in some systems...and they may need to be added to others.

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Once a reasonable period has elapsed with the :urrent maintenance plan, the Optimization system nay direct a variation. Knowledge-based analysis of he plan may reveal the stocking levels are higher than iecessary, that certain condition monitoring tests are nappropriate, or that in some way altering the mix of naintenance resources may move the system closer to ın optimal level. At this point, the Configuration Module, with the approval of the maintenance ›lanner, will reconfigure the other modules to implement the new plan.

A word of warning...*any* attempt to optimize a ystem requires a method that effectively measures he performance of the system. It is impossible to ıpply optimization techniques to a process if there are ıo criteria that can assess whether any changes ›roduce better or worse results. Objective, numerical neasurements are needed before any steps can be aken to increase the effectiveness of a process or ystem.

In the field of management science, the search for neasurement criteria for a system comes under the :eneral title of metrics. Different measurement criteria ıre applied to a system, in an attempt to quantify the ·ffectiveness, not of the system, but of the neasurement criteria themselves.

Do you want to measure the quality of an ıssembly line system? Measure defects per hour, :efects per item produced, defect severity levels, ıours spent on inspection, hours spent on rework; the ist can be extremely long. In many cases, measure:nents are redundant or inappropriate. The discipline ·f metrics is used to determine the correctness of ıeasurements applied to a system. Once a useful set ·f metrics are determined, these measurements can be ıe objective standards used to drive the process of ystem optimization.

Without a set of metrics to measure maintenance ractices over time, the ability to determine ·bjectively the effect of changes to the maintenance peration becomes extremely difficult.

The cycle of operation illustrated in Figure 3 is a ontinuous cycle. The system is configured, operated, nalyzed and reconfigured on an ongoing basis. The ıark of a healthy maintenance operation is one where ɔme of the optimization decisions will have negative :sults and need to be changed back; after all, if any hange made to a system is a good one, a whole bunch f things must be getting done badly!

Eventually, however, the operation should pproach optimal performance, and the number of lterations to the system should decrease. Even then, n optimizing system will still produce benefits, as it a rare industry whose operating environment :mains unchanged over time, and an optimizing ystem is better able to respond to changes in its nvironment.

The system described is clearly not available ›day, and will probably not be generally available for uite some time. However, it should be noted that a roject in this area has been in effect for nearly four :ars, and is slated to continue for several more. The 'anadian Coast Guard, in conjunction with the Canadian Department of Transport, has been funding and implementing research work in the field of intelligent diagnostic systems since 1989.

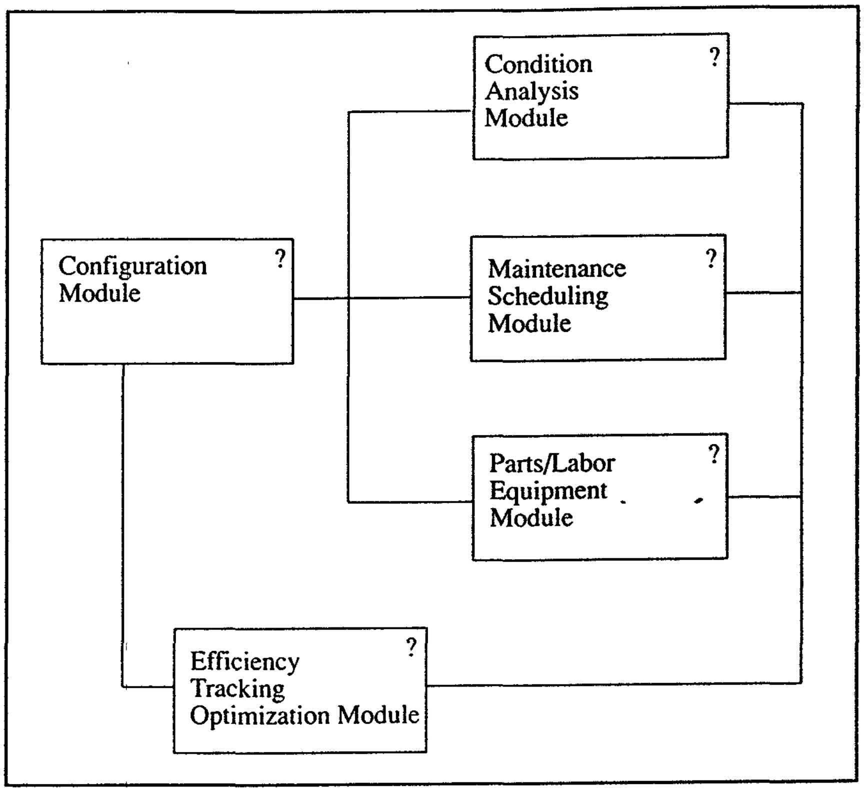


Figure 3 -
Operation illustrated is a continuous cycle. The system is configured, operated, analyzed and reconfigured on an ongoing basis. The mark of a healthy maintenance operation is one where some of the optimization decisions will have negative results and need to be changed back.

The current phase of this ongoing project is called PUMP, the Predictive Upkeep and Maintenance Program. The PUMP system's purpose is to integrate the findings from subsystems in vibration analysis, lubricant analysis, engine performance analysis, inventory and maintenance history. These integrated findings will be used to update/alter maintenance schedules. In the future, it will be an essential component for an optimized maintenance management system.

For more information contact Stephen Reilly, Design Maintenance Systems, Inc., 200-340 Brooksbank Ave., North Vancouver, BC V7J 2C1 CANADA; (604) 984-3674; or SKF Condition Monitoring, 4141 Ruffin Rd., San Diego, CA 92123; (619) 496-3400.

The system described is clearly not available today, and will probably not be generally available for quite some time. However, it should be noted that a project in this area has been in effect for nearly four years, and is slated to continue for several more. The Canadian Coast Guard, in conjunction with the Canadian Department of Transport, has been funding and implementing research work in the field of intelligent diagnostic systems since 1989. The current phase of this ongoing project is called PUMP, the Predictive Upkeep and Maintenance Program. The PUMP system's purpose is to integrate the findings from subsystems in vibration analysis, lubricant analysis, engine performance analysis, inventory and maintenance history. These integrated findings will be used to update/alter maintenance schedules. In the future, it will be an essential component for an optimized maintenance management system.

TABLE 1 SUMMARY OF COATING PERFORMANCE

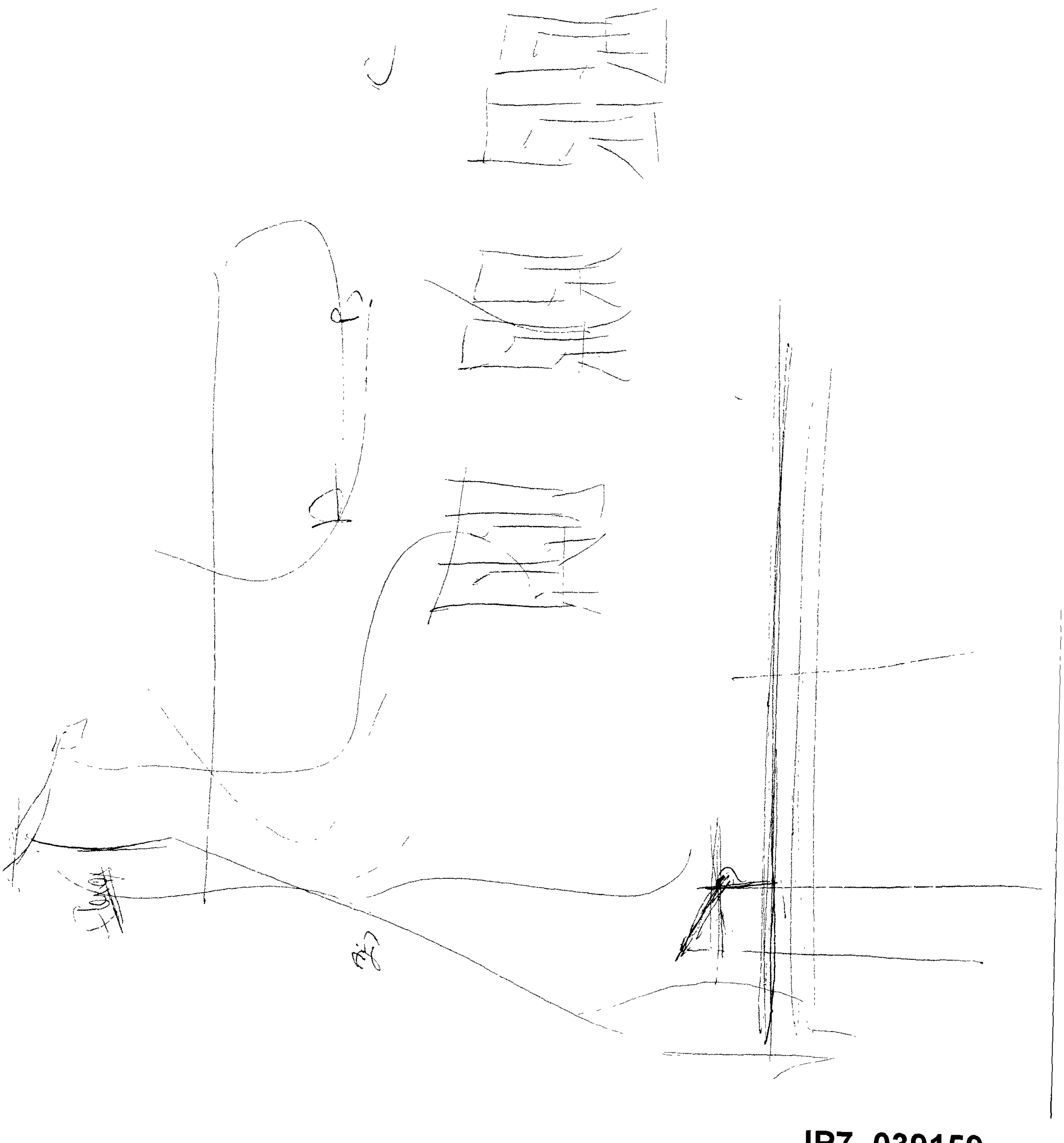
COATING	SURFACE PREP. REQR.	THICKNESS	ADHESION (Pull Test)*	COMMENTS
ARCOR S-16	White metal blast, 4.5 mil profile	42 mil	Coating @ 200 psi (1993) Coating @ 250 psi (1993) Coating @ 50 psi (1994)	Looks good but adhesion is poor. Substrate wet beneath coating removed.
ARCOR S-15	White metal blast, 4.5 mil profile	33 mil	Coating @ 250 psi (1993) Coating @ 500 psi (1993) Est. < 100psi (1994)	Some deterioration is appearance, poor adhesion. Substrate wet beneath coating removed.
ARCOR TS-RB	White metal blast, 4.6 mil profile	200 mil	No Coating Failure(1993) Glue @ 500psi (1994) Glue @ 600psi (1994) Glue @ 900psi (1994)	Highest measured adhesion. No deterioration in appearance or adhesion with time.
SPECO SPEFLEX	White metal blast, 3 mil profile. Preheat surface	30 mil	No Coating Failure(1993) Glue @ 250psi (1994)	No deterioration in appearance or adhesion. Best of evaluated "thin coat" systems.
DEVOE DEVRON 184	Near white metal blast, 2 mil profile	16-20 mil	Coating @ <100 psi(1993) Coating @ <500 psi(1993) Not tested 1994	Discolored, blistered, poor adhesion.
PLASTOCOR 400K	Water blast White metal blast, 3 mil profile	200-250 mil	Coating @ 400 psi (1993) No Coating Failure(1993) Glue @ 100 psi (1994)	Good appearance & performance, good adhesion but lower than Arcor TSRB or Speco Speflex.
PALMER CL 600		200-250 mil	*Applied in 1993* Glue @ 450 psi (1994)	Good appearance and performance. Adhesion greater than 450 psi.

* The glue bond between the dolly and coating surfaces broke at approx. 500 psi on all cases designated as "No Coating Failure".

tubesheet (thick)
waterbox (thin)

Call Bucket Tips Suppliers

Call: John Bell



SW/SAS rotating throats

got copy Cecil's report

Grinding Component Wear
As expected, tire wear rates decreased slightly during the time the SAS throats were tested. The newly calculated wear rate would only extend tire life approximately 2 months.

Summary
Based on test results and maintenance records, the SAS rotating throats offer the following advantages and disadvantages:

Advantages
1. **Installation** requires only two days for the SAS throats.
2. **Maintenance labor** would be minimal considering the wear noticed during the test and the ease of replacing worn chrome carbide liners.
3. **Motor current and dP are not negatively affected.**

Disadvantages
1. **Fineness, particularly retainage on 30 and 50 mesh**, with the SAS will likely be detrimental to Unit efficiency. B&W and EPRI reports that unburned carbon losses and NOx can be correlated with the percentage retained on 30 and 50 mesh. The sale of flyash would likely be affected also.
3. **Overall fineness, according to the B&W curves, failed consistently.**

CONCLUSIONS

SOUTHWESTERN

Fineness
Fineness was either coarser than normal or too fine. The increase of 30 and 50 mesh retainage with the original throats was likely caused by the high air velocity through the undersized throat ports.

Widening the throats dropped air velocity to the lower design threshold resulting in overgrind. Evidence of overgrind includes increased motor load, higher inlet temperatures and 30 and 50 mesh retainage at a consistent 0.10 percent. The effect of overgrind is reduced mill throughput, additional liberated moisture requiring evaporation, increased grinding component wear and increased mill power consumption.[8]

If a resolution to the Southwestern throat problem is possible, it can only be done by increasing throat velocity without

[8] 'Pulverizer System Performance' - Dec. 1992. James K. Lafontaine